AUTOMATED, INTERCEPT-TO-GROUND, LETHALITY COLLATERAL EFFECTS ESTIMATION FROM KEW INTERCEPTS

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Abstract

The Lethality Division of the Weapons Directorate of the United States Army Space and Missile Defense Command (USASMDC) has developed the Post Engagement Ground Effects Model (PEGEM) to provide chemical, biological, nuclear and high explosive weapons hazard assessment in the form of ground collateral effects. PEGEM is a "fully automated end-to-end" computer software simulation. PEGEM was initially developed to assess the results of fragmenting warhead and hit-to-kill (HTK) interceptors impacting with Theater Ballistic Missiles, but customer demand has dictated additional capabilities (i.e., leaker and cruise missile assessment) be built into the model. PEGEM represents a true multi-service effort with contributions from the Army, Navy, Air Force, as well as other government agencies and contractors. Output of the program is in the form of agent cloud positions and dimensions, coverage area, and estimating casualties at specified times-of-interest. PEGEM also supports the Army Unit Resiliency Analysis (AURA) model through dedicated outputs and Extended Air Defense Simulation / Extended Air Defense Test Bed (EADSIM/EADTB) with a real-time Distributed Interactive Simulation (DIS) interface and a preprocessor standalone mode.

PEGEM is an integration of previously existing and new models. Typically an analyst specifies a multiple threat scenario including all threat details and the locations and times of the events. Lethality information is usually provided through the output of the Parametric Endo/Exoatmospheric Lethality Simulation (PEELS) code. High altitude and boundary layer atmospheric transport is carried out by the Vapor, Liquid, and Solid Tracking (VLSTRACK) model. Surviving submunitions are propagated to the ground using one of two semi-empirical flyout models, tailored to the munition characteristics. Once ground impact locations of the munitions are estimated and atmospheric transport calculations complete, casualty estimations are generated based on current CBW toxicology and/or high explosive (HE) standards. PEGEM is being class accredited by BMW with a goal of completion by the year 2000 for the Navy and Army Anti-Ballistic Missile System missiles.

Collateral Effects Estimation

The Post-Engagement Ground Effects Model (PEGEM) is a comprehensive simulation tool that provides automated ground collateral hazard assessment primarily from chemical, biological and conventional warhead TBM weapons. Output of the model is in the form of chemical or biological agent ground contamination, and/or dosage footprints, as well as estimated casualties at user-specified times-of-interest. In addition, PEGEM estimates overpressure and fragment effects on unprotected personnel from blast-fragment types of submunitions, unitary weapons, as well as falling RV and interceptor debris. PEGEM encompasses a number of modeling areas in order to assess ground collateral effects from High Explosive (HE), chemical and biological payloads. Modeling of the ground environment can also be accomplished through sensor, population, and terrain manipulation (see Figure 1). PEGEM also interfaces and communicates with other simulations via the Distributed Interactive Simulation (DIS) network and also through I/O files and databases. These linkups and connections allow the model to provide and acquire threat, scenario, and situational information to a plethora of other systems. Continuing proliferation of TBM, cruise missile, and other delivery systems for Weapons of Mass Destruction (WMD) to Third World Nations causes concern for both military and civilian populations. Potential threats may arise either from direct attacks, or from collateral effects following intercepts of chemical and biological weapon payloads. PEGEM provides an automated system of models and simulations that an operator can use to assess the effectiveness of anti missile systems and ground situations, in both intercepted and unintercepted cases.

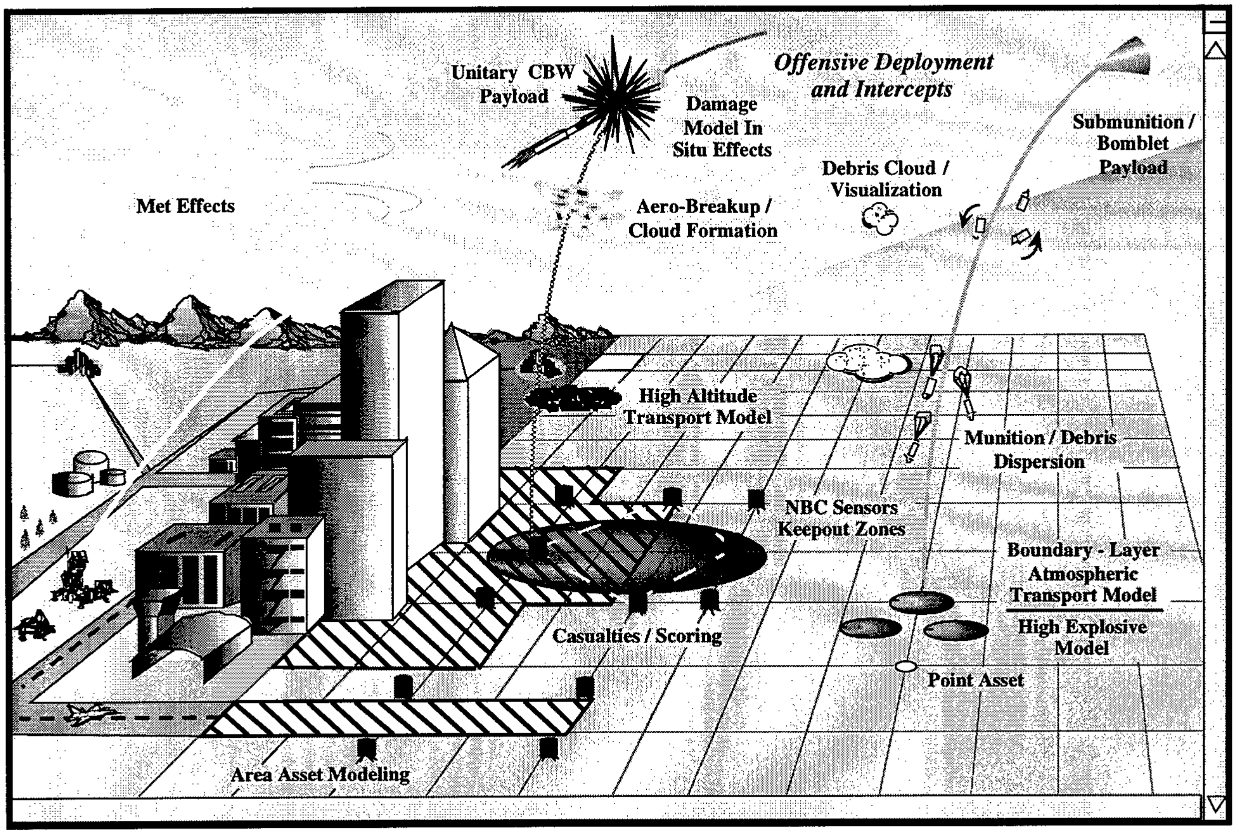

Figure 1
Scope of PEGEM

The PEGEM simulation is an integration of several previously existing models, as well as models developed for this application. Figure 2 illustrates the general architecture and external interfaces. This paper will briefly describe these elements of PEGEM and their automated linkup; complete details may be found in References 1 and 2. PEGEM was originally conceived to address the TBM ground collateral threat posed by a chemical or biological weapon intercept. The predecessor models were all hand integrated, labor-intensive operations in which many manual steps were implemented to provide estimation of ground collateral effects. Trajectory information, weapons operational and timeline data, as well as source term and environmental details, aero-physics, transport and dispersion, casualty/toxicity and other models all had to be integrated together manually before the PEGEM system was developed. PEGEM provides a common benchmark/system to not only automate, but document and record analysis, as well as providing a more convienent means to reproduce results. In a typical case, the analyst specifies all chemical, biological or high explosive weapons in the scenario including all threat, ground and environmental details and the locations and times of the dissemination events. These selections are currently made through command line input for version 2.1, but will be built in to a Graphical User Interface (GUI) for version 3.0. Standard analysis files will also be available in version 3.0 that provide a standard scenario and threat to speed up simple analysis concepts. Intercept lethality information can be provided through the output of an endgame lethality simulation code such as the SMDC/BMDO Parametric Endo Exo Lethality Simulation (PEELS). The lethality simulation code provides PEGEM a prediction of the fraction of payload surviving following an intercept event. For submunition payloads, the locations of surviving munitions within the target payload along with data describing the impact are provided. If this information is not available for the intercept condition, the data can be supplied externally and varied for parametric analysis, if desired. This information is used by PEGEM as the starting point to propagate the residual threat(s) to the ground.

Given endgame data for submunition payloads, PEGEM determines ejection velocity vectors of surviving submunitions and debris using a semi-empirical methodology. This methodology is derived from relationships between endgame characteristics and ejection velocities established through extensive review

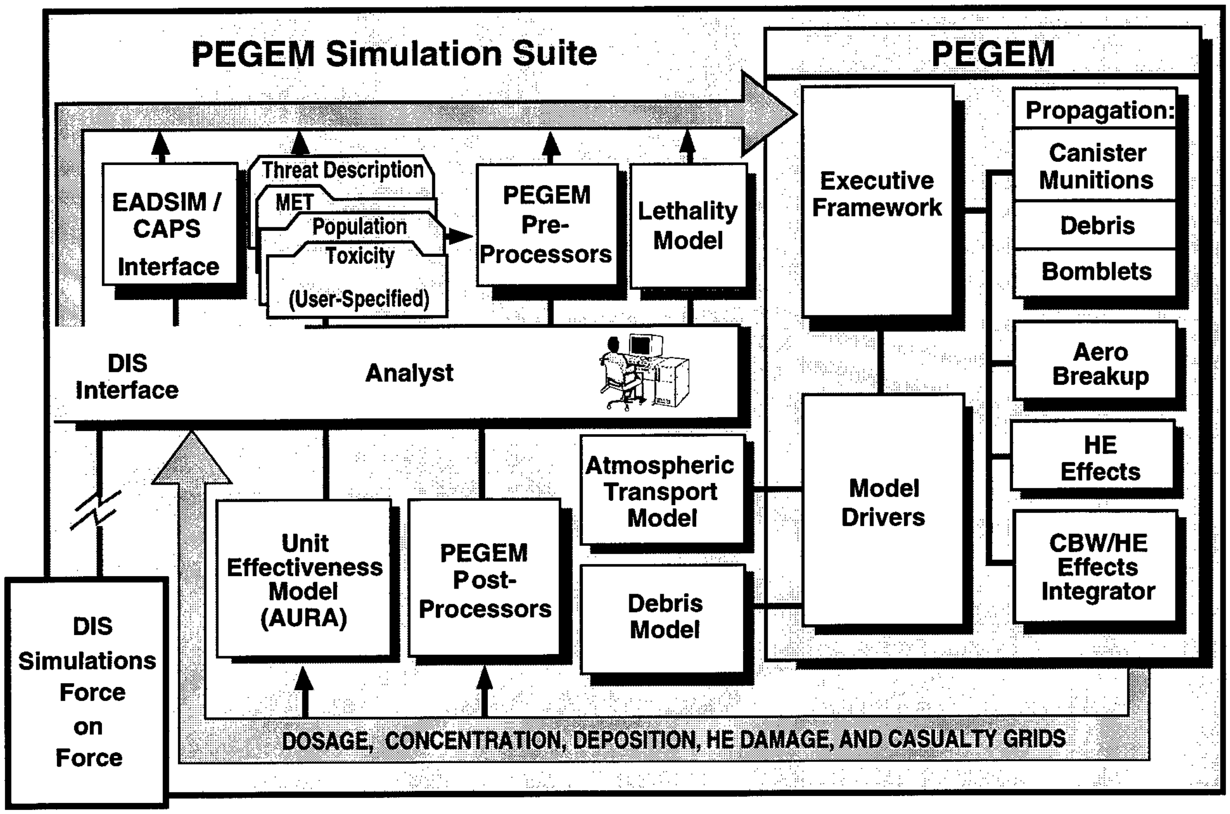

Figure 2
PEGEM Architecture and External Interfaces

of data from high-speed impact sled tests, quarter-scale light-gas gun tests, and hydrocode analysis for the submunitions. A similar approach is used in the KIDD simulation which computes the initial debris source term. Once initial velocity vectors are determined, submunitions are propagated to the ground using a three degree-of-freedom (3-DOF) model with munition drag data for each phase of the flight, (tumbling to streamer/chute stabilized). Certain munitions with more complex flight characteristics require use of a six degree-of-freedom model. With either flyout approach, wind effects on submunition and debris propagation are included. Meteorological (MET) data are provided to PEGEM through a stratified atmosphere model that provides wind velocity as a function of altitude for a given time. A MET profile can be specified at multiple times, which can be linearly interpolated by PEGEM in flyout calculations. MET data can be built manually, imported from outside or a specific profile from the built in statistical database can be selected for the analysis.

In contrast to submunition payloads, unitary chemical payload analyses require the PEGEM Aerodynamic Breakup Module (ABM) to characterize the initial chemical agent source cloud that results when a threat is intercepted, or when it is operationally dispensed into the atmosphere at high speed. This module determines chemical agent line source length, lateral dimension, and agent droplet size distribution as a function of release conditions. The empirically based approach is derived from results of recent BMDO extensive agent simulant testing and historical data.

Once the initial source cloud is described, an atmospheric transport and dispersion model (Reference 3) determines ground deposition, dosage, and concentration from a unitary release. This model calculates the transport, evaporation, and diffusion of tri-variate gaussian puff clouds of liquid, vapor, and in some cases, solids. Since casualty calculations will be based on short-term cumulative contamination levels, the atmospheric transport model is normally run in a cumulative mode. As with the previously described flyout models, the atmospheric transport model uses interpolated MET data in performing transport calculations. Output of the atmospheric transport model is in the form of deposition, dosage, and concentration. Deposition is a measure of liquid contamination area coverage and is typically measured in milligrams of agent per square meter. Concentration is a instantaneous volumetric measure of agent contamination and is measured in milligrams per cubic meter, usually at a specified height above the ground

(~2 m for personnel effects) throughout an area. Dosage is the time integral of concentration, taking into account not just level of exposure, but time exposure as well. Dosage is typically given in units of milligrams-minutes per cubic meter.

High explosive unitary threats are usually ground impact detonated and are more simplistic in evaluation since there is not a transport or dispersion of agent. The user can select the effects of the detonation which interest them the most, either blast or fragment casualty effects on the modeled population. Casualty data is the only direct output from the HE analysis.

CBW submunition payloads also require the use of the atmospheric transport and hazard assessment model. Once the ground impact points of munitions have been determined using the appropriate flyout module, munitions are assumed to undergo normal (usually ground level) detonation. The initial source cloud from the detonation is provided and the resulting deposition, dosage and concentration are determined. HE submunitions are handled very similarly until impact and detonation. The transport and dispersion model is not needed for HE and the casualty effects are estimated directly based on the specific threat and ground environment characteristics.

Debris ground footprints for unitary or submunition intercepts is provided for CBW unitary and submunition payloads and consists of probability of impact and casualty zones. These footprints will contain contributions from both interceptor and RV debris.

Once ground deposition, dosage, concentration, and probability zones for all threats are determined, the final steps in the simulation are to produce contamination grids and calculate casualties. The PEGEM Effects Integrator Module (EIM) convolves atmospheric transport model contamination grids, discrete population data, and probit methodologies for assessing toxicity and blast/fragment/debris effects to produce casualty estimates. The CBW approach for estimating casualties is a standard probit-based approach originally proposed by D.J. Finney (Reference 4) for probabilistically determining response to a pathogen. This approach requires that response data be available in order to determine a median lethal effective dosage or deposition value for the agent in question, along with the probit-response slope which describes the rate of change of effectiveness as dosage or deposition level is changed. These toxicity data are often derived from extensive tests on mammals including, in some limited cases, humans. Chemical agent toxicity data employed by PEGEM are derived from a recent toxicity standard report (Reference 5). Similar standards are currently being compiled for agents of biological origin (ABO). Casualties from blast/fragment and falling debris are calculated from response data Standards compiled by the US Government. This data has a long pedigree from extensive test and field data generated in the last century.

Population data for casualty estimations are currently drawn from a database compiled by the Department of Commerce, Bureau of Census. The data are provided for many non-U.S. urban areas in seventy-eight countries (Reference 6).

As an alternative to the existing population database within PEGEM, users may specify their own population field. An important asset of PEGEM is the ability to specify population data to any desired level of fidelity. Often, sensitivity studies are executed where intercept or chemical agent properties are varied. In these cases, only the relative effect of changing a parameter is needed, hence, the fidelity of the population is not of great concern. In these cases, uniform population densities can be employed. In other cases, very specific predictions might be desired where the locations of certain individuals or assets becomes important.

An example theater ballistic missile (TBM) chemical attack scenario is shown in Figure 3. In this case, a bulk chemical and a chemical submunition payload offensively deploy under the following conditions:

	BULK CHEMICAL PAYLOAD	CHEMICAL SUBMUNITION PAYLOAD
Agent	Thickened VX (Nerve Agent	GB (Sarin)
Fill Weight	500 kg	1 kg
Munitions	1	50
Deployment Altitude	1000 meters	2000 meters

For this example, an infinite uniform population distribution with 1000 people per square kilometer is selected. A constant 10-km/hr wind is assumed for transport purposes. Casualties from the bulk chemical and chemical submunition threat are 3,680 and 50, respectively.

By running the same case again, but this time with intercepts of the payloads, the relative effectiveness of the intercepts can be evaluated (Figure 4). For this case, both payloads are assumed to be intercepted by a hit-to-kill interceptor at an altitude of 5 km. Assume an external lethality simulation code calculates that 50% of the bulk chemical payload is mitigated by the intercept,

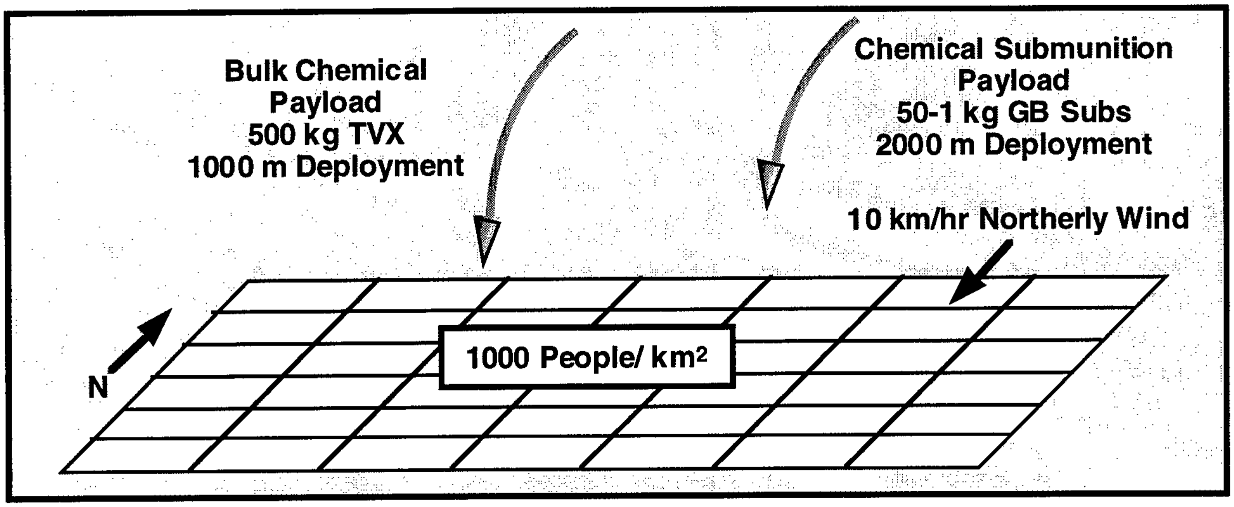

Figure 3
TBM Attack Scenario

and 80% of the submunition payload target is destroyed. The surviving submunitions are (conservatively) assumed to fall to the ground and function as designed upon impact.

PEGEM determines that for this scenario, the residual bulk chemical agent dispersed at 5-km produces no casualties. This is because the agent that survived the intercept was dispersed before it could reach the ground in lethal quantity for this MET condition. The ten surviving chemical submunitions resulted in seven casualties, which represents fourteen percent of the baseline value. Clearly, in this case the intercept was effective in mitigating the threat posed by the two chemical weapons. PEGEM typically completes calculations for a scenario of this low complexity in under one minute on a 233 MHz Pentium PC.

PEGEM is capable of modeling multiple weapons attacks over a user-specified period of time; hence, output produced can become voluminous. The graphical post-processor (Hot Plot) provided with PEGEM can be very beneficial for interpreting these

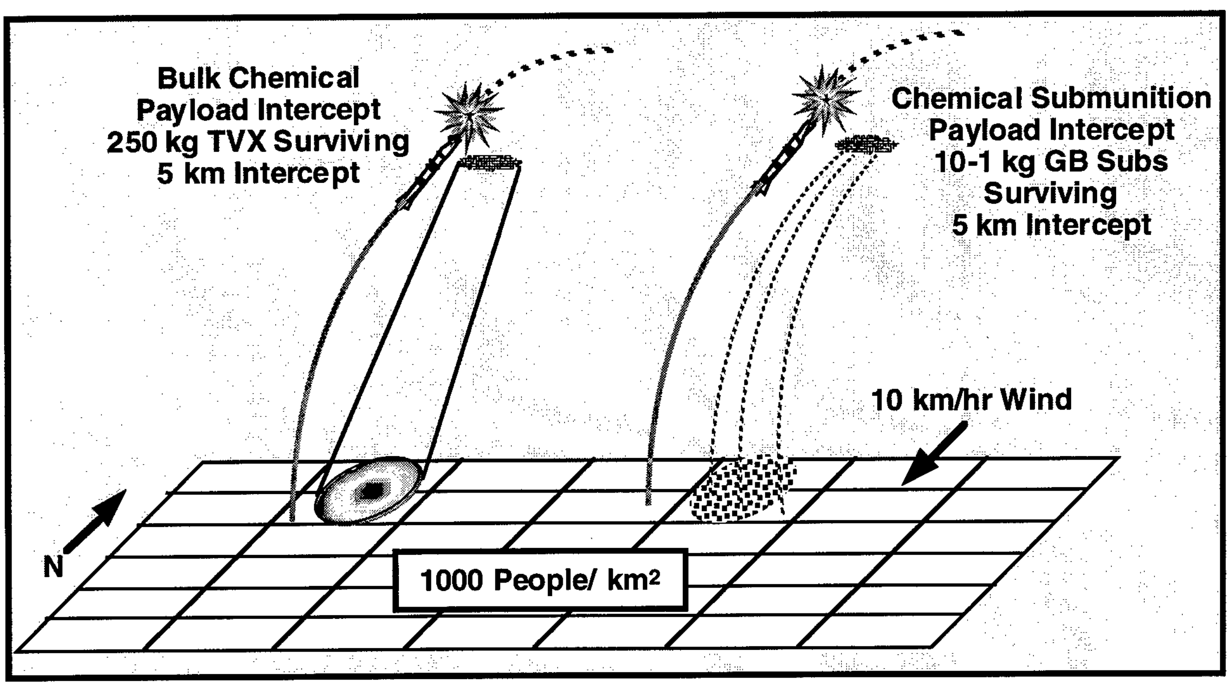

Figure 4
TBM Intercept Scenario

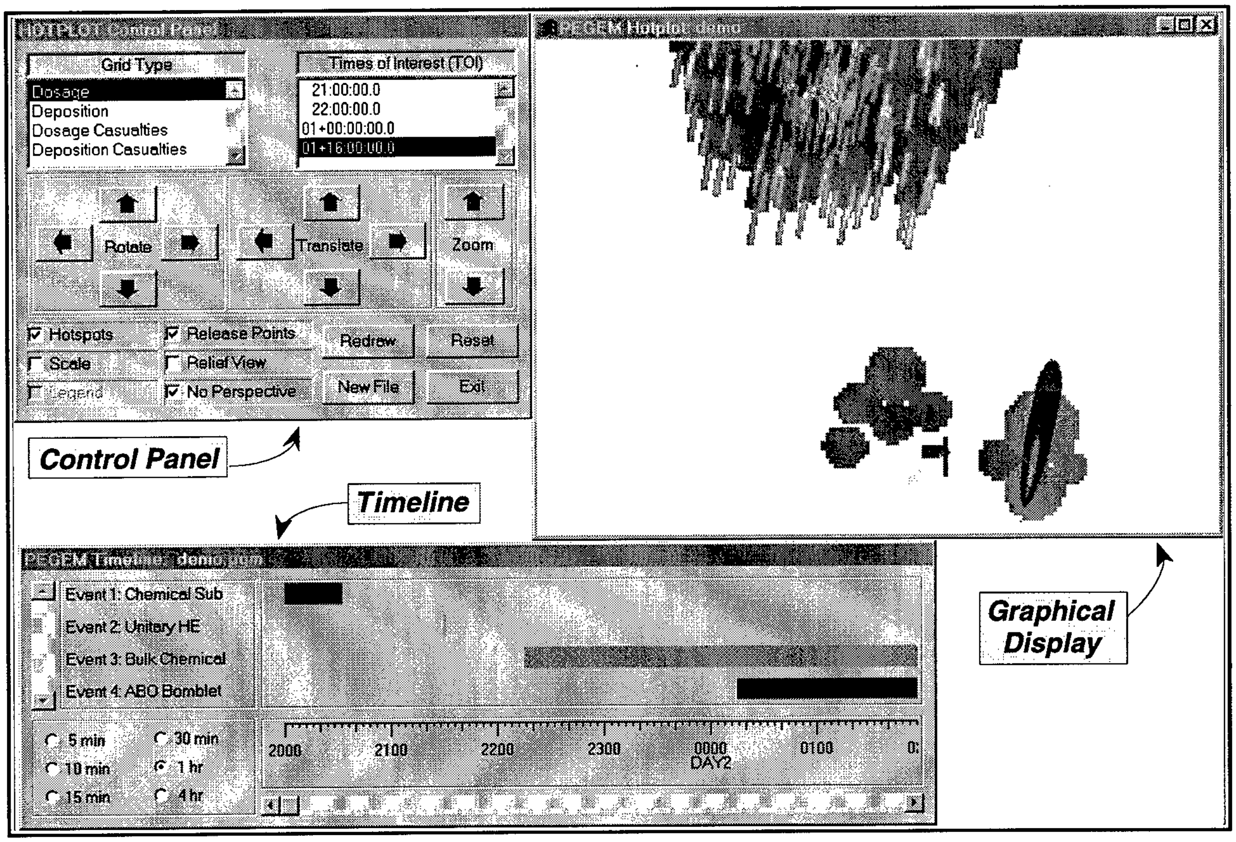

Figure 5
Hotplot Display Screen

results. Users can quickly assess the location and extents of ground contamination relative to ground assets or population and visualize the release and impact points. A typical output plot from hotplot is depicted in Figure 5. In this figure the control panel, timeline indexer, airfield and population examples (yellowish circles) are shown with biological, chemical and HE effects.

In the past, interceptor effectiveness was measured in terms of hitting or missing the target, or in more recent times, in terms of damage to the target. PEGEM complements these methodologies by providing answers to questions concerning what happens to the payload that survives the engagement. Also of benefit and provided by PEGEM is how intercepted situation compares to the unintercepted case. CBW intercept lethality and system effectiveness can now be measured in terms of the effects ultimately reaching the ground. The next step is to expand this baseline PEGEM capability for chemical, biological, and HE weapons to include effects from other weapons types and additional collateral effects such as nuclear. To this end, future efforts will include integration of straightforward way to model cruise missiles, artillery and eventually nuclear weapon effects models.

Recently, a seamless interface was completed between PEGEM and the Extended Air Defense Simulation (EADSIM). Coupled with EADSIM, PEGEM can help evaluate the effects of chemical, biological and conventional weapon attacks on military units in a Force-on-Force environment. In the future, PEGEM will pass its environmental effect data to these models through standard High Level Architecture (HLA) data exchange units. These efforts will enhance the utility of PEGEM by making its continuously expanding output available for use in simulations of an even wider scope.

PEGEM is an important tool for assessing the hazard presented by chemical, biological, conventional agents and debris. Future enhancements will expand its capabilities to other threat types, expanding the unitary regime of aero-resoponse and producing a complete theater missile defense collateral effects tool. Armed with greater knowledge about threats through models such as PEGEM, improved military defense systems and protective measures are possible.

References

1. *Post Engagement Ground Effects Model Version 2.1 User's Manual Draft*, MEVATEC Corporation, October 1997.

2. *Post Engagement Ground Effects Model Version 2.0 Technical Manual Draft*, MEVATEC Corporation, October 1996.

3. Bauer, T., *Software User's Manual for the Chemical / Biological Agent Vapor, Liquid, and Solid Tracking (VLSTRACK)) Computer Model, Version 1.6.3,* Naval Surface Warfare Center, 1997.

4. Finney, D. J., *Probit Analysis*, Cambridge GB, Cambridge University Press, 1971.

5. Reutter, S., and Wade, J. LTC, *Review of Existing Toxicity Data and Human Estimates for Selected Chemical Agents & Recommended Human Toxicity Estimates Appropriate for Defending the Soldier (U)*, Edgewood Research Development & Engineering Center, 1994.

6. Pitman, S., and Scollard, J., *Urban Population (P95) Volume 1 - Middle East*, Science Applications International Corporation, July 1991.